

# Claims

- [c1] A method of forming a semiconductor device on a semiconductor substrate, comprising the steps of:  
forming a wide trench and a narrow trench in the substrate;  
forming a first electrode in the narrow trench by depositing a first fill material of a first conductivity type over the device to fill the wide trench partially and filling the narrow trench completely and then etching back the first fill material until completion of removal thereof from the wide trench;  
forming a second electrode in the wide trench by filling the wide trench with a second fill material of an opposite conductivity type; and  
annealing to drive dopant from the first electrode into a region in the substrate about the periphery of the narrow trench, and to drive dopant from the second electrode into a region in the substrate about the periphery of the wide trench.
- [c2] The method of claim 1, wherein only a single set of masks is employed to produce the device including only one layer of resist and only one hardmask layer.

- [c3] The method of claim 1, wherein a liner is deposited into the narrow trench and the wide trench prior to deposition of the first fill material.
- [c4] The method of claim 1 including forming a contact to the first electrode and forming a contact to the second electrode.
- [c5] The method of claim 1 including forming a cap layer over the device prior to annealing.
- [c6] The method of claim 1, wherein the material of the first conductivity comprises N-type doped polysilicon and the material of the second conductivity comprises P-type doped polysilicon.
- [c7] The method of claim 1, wherein the material of the first fill material comprises N-type doped polysilicon and the material of the second fill material comprises P-type doped polysilicon.
- [c8] The method of claim 1, wherein the semiconductor substrate is formed over a buried oxide layer.
- [c9] The method of claim 1, wherein the semiconductor substrate is composed of a material selected from the group consisting of Si, strained Si,  $\text{Si}_{1-y}\text{C}_y$ ,  $\text{Si}_{1-x-y}\text{Ge}_x\text{C}_y$ ,  $\text{Si}_{1-x}\text{Ge}_x$ , Si alloys, Ge, Ge alloys, GaAs, InAs, InP as well as other

III–V semiconductors, II–VI semiconductors, Si-containing materials, a Silicon–On–Insulator (SOI) substrates or a SiGe–On–Insulator (SGOI) substrates.

[c10] The method of claim 1, wherein the liner material is composed of a material selected from a group consisting of silicon nitride, Ge, SiGe, WSix, TiN, Ta, Ti, and SiC.

[c11] A method of forming a photodetector device on a semiconductor substrate, comprising the steps of:  
forming a wide trench and a narrow trench in the substrate;  
forming a first electrode in the narrow trench by depositing with a first fill material of a first conductivity type over the device thick enough to fill the wide trench partially and filling the narrow trench completely and then etching back the first fill material until completion of removal thereof from the wide trench;  
forming an epitaxial semiconductor layer in the wide trench leaving a narrowed wide trench therein;  
forming a second electrode in the wide trench by filling the wide trench with second fill material of an opposite conductivity type; and  
annealing to drive dopant from second electrode into a region in the substrate about the periphery of the wide trench and to drive dopant from the first electrode into a region in the substrate about the periphery of the narrow

trench.

- [c12] The method of claim 11, wherein only a single set of masks is employed to produce the device including only one layer of resist and only one hardmask layer.
- [c13] The method of claim 11, wherein a second liner is deposited into the narrowed wide trench prior to deposition of the second fill material.
- [c14] The method of claim 11, wherein a liner is deposited into the narrow trench and the wide trench prior to deposition of the first fill material.
- [c15] The method of claim 14, wherein a second liner is deposited into the narrowed wide trench prior to deposition of the second fill material.
- [c16] The method of claim 13 including forming a silicide contact to the first electrode and forming a silicide contact to the second electrode.
- [c17] A semiconductor device on a semiconductor substrate, comprising:
  - a wide trench and a narrow trench in the substrate;
  - a first electrode formed in the narrow trench composed of a first fill material of a first conductivity type;
  - a second electrode formed in the wide trench composed

of a second fill material of an opposite conductivity type;  
and  
a first outdiffusion region doped with dopant diffused from the first electrode into a region in the substrate about the periphery of the narrow trench and a second outdiffusion region doped with dopant diffused from the second electrode into a region in the substrate about the periphery of the wide trench.

- [c18] The device of claim 17 wherein the semiconductor device is a photodetector.
- [c19] The device of claim 17 wherein an epitaxial silicon layer is formed on trench sidewalls of the wide trench leaving a space filled with the second electrode.
- [c20] The device of claim 17 wherein the wide trench with the epitaxial layer formed on trench sidewalls has the same opening size as the narrow trench.